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A Comparison of Carbon Cycling and the Surface
Energy Balance between Native Perennial and
Exotic Annual Grass Communities in Northern
Coastal California

There's been a major shift in California Grassland Species



From native perennial

to

Exotic annual grasses

Objective

- To understand how the shift in grassland communities has affected climate.
- Through changes in carbon cycling and terrestrial storage of carbon.
- Through changes in the surface energy balance.

Approach

- Small-scale ecological study at two sites where native and exotic grassland species exist alongside each other in discrete patches.
- Observational study involving tools from biogeochemistry, biometeorology and plant ecology.

Today's Talk

- A Little Background and Context
- Brief description of my research project.
- Some preliminary findings of my research.

Background

Our Ecosystems are Changing

- The causes are manifold. To list but a few...

Urbanization, Deforestation, The spread of invasive species,
Land clearance for agriculture and livestock grazing,
Overgrazing, The spread of toxic substances and pollutants,
Nitrogen deposition, Climate change, Damning and
diversion of waterways...

Ecosystem Change Impacts: The Scope of the Phenomenon

Land use/Ecosystem change accounts for approximately one third to one half of anthropogenic climate change. The land surface has been transformed from approximately 20% of all CO₂ emissions to a smaller set of species that are most successful in fragmented and degraded land. Much larger regions have been fragmented by human activities (other damaging exotic grasses from Europe and Asia that have invaded California, as well as numerous other invasive species).

Ecosystem Change in California Grasslands

Widespread shift in California grasslands from native perennial to exotic annual grasses began in the 1700s

Today there is greater than 95% exotic grass conversion over 10 million acres in CA

California State Flag



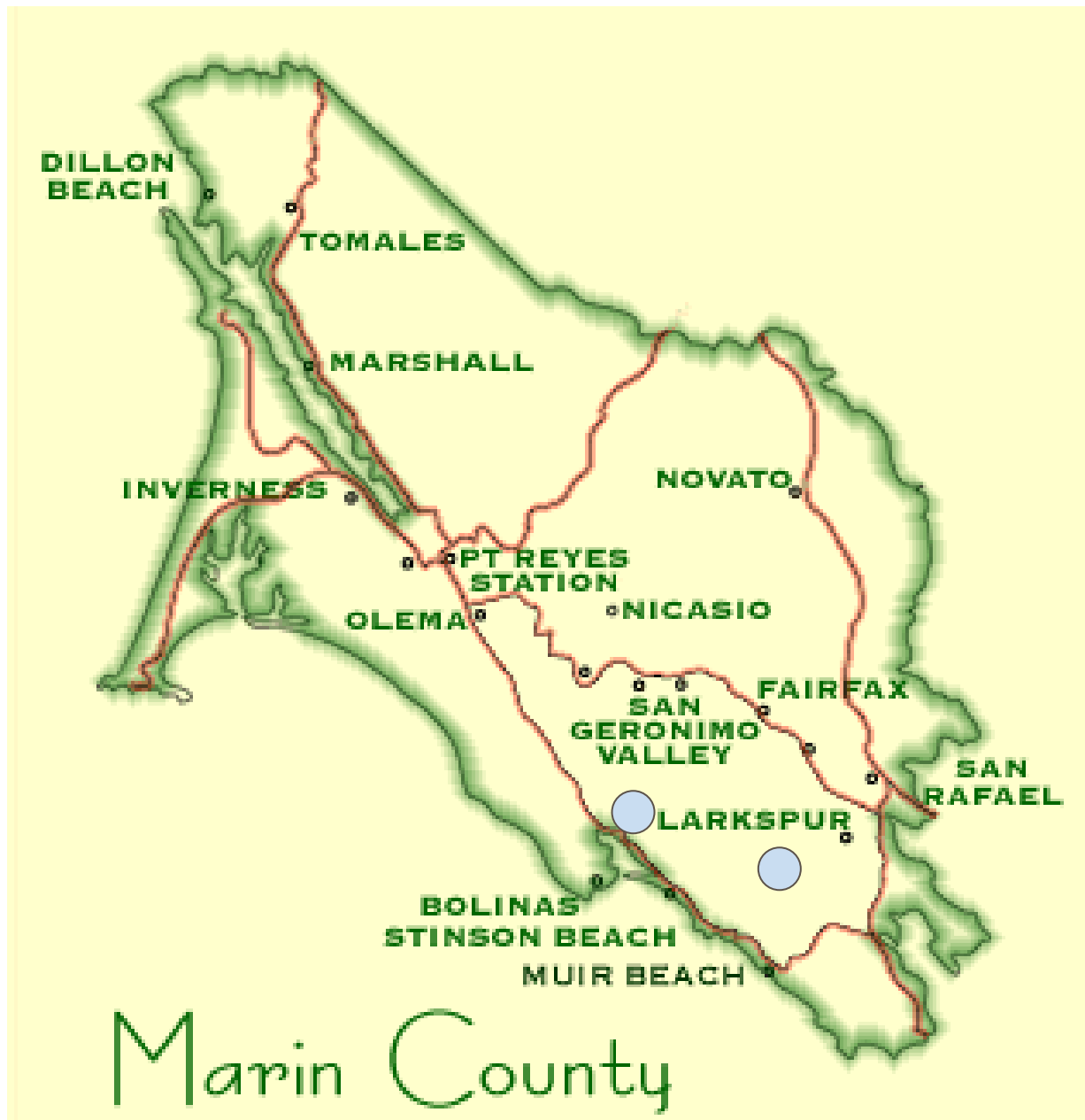
Primary Causes of Grassland Shift

- the progressive clearance of land for livestock grazing and agriculture, and subsequent agricultural abandonment.
- fire suppression: fire can favor native perennials.
- periods of severe drought in which native grasses died, and seed limitation of native grasses relative to exotic annuals allowed for annual grass dominance.
- the deliberate and accidental introduction of exotic grasses from Europe and Asia for grazing.
- Competition mediation by the yellow-dwarf virus.

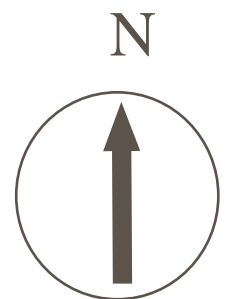
The Study

Questions

1. What differences exist between native perennial and exotic annual grass ecosystems in the ways they cycle and store carbon among the atmosphere, plant biomass and the soil?
2. What differences exist between native and exotic grass ecosystems in the ways they cycle water and energy among the atmosphere, plant biomass and the soil?
3. How is climate affected?



● Study Locations



Plot Layout Schematic ~ Tennessee Valley



Down Slope 5%

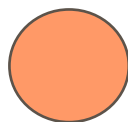


Prevailing Wind
Direction



Tennessee Valley

Micromet Station:
Native grass



Native Grasses

Festuca rubra



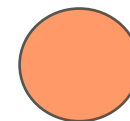
Agrostis halli



Exotic Grasses



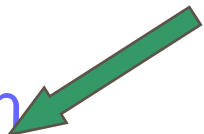
2 x 2 m
plots



Micromet Station:
Exotic grass

Elevation:
App. 250 m

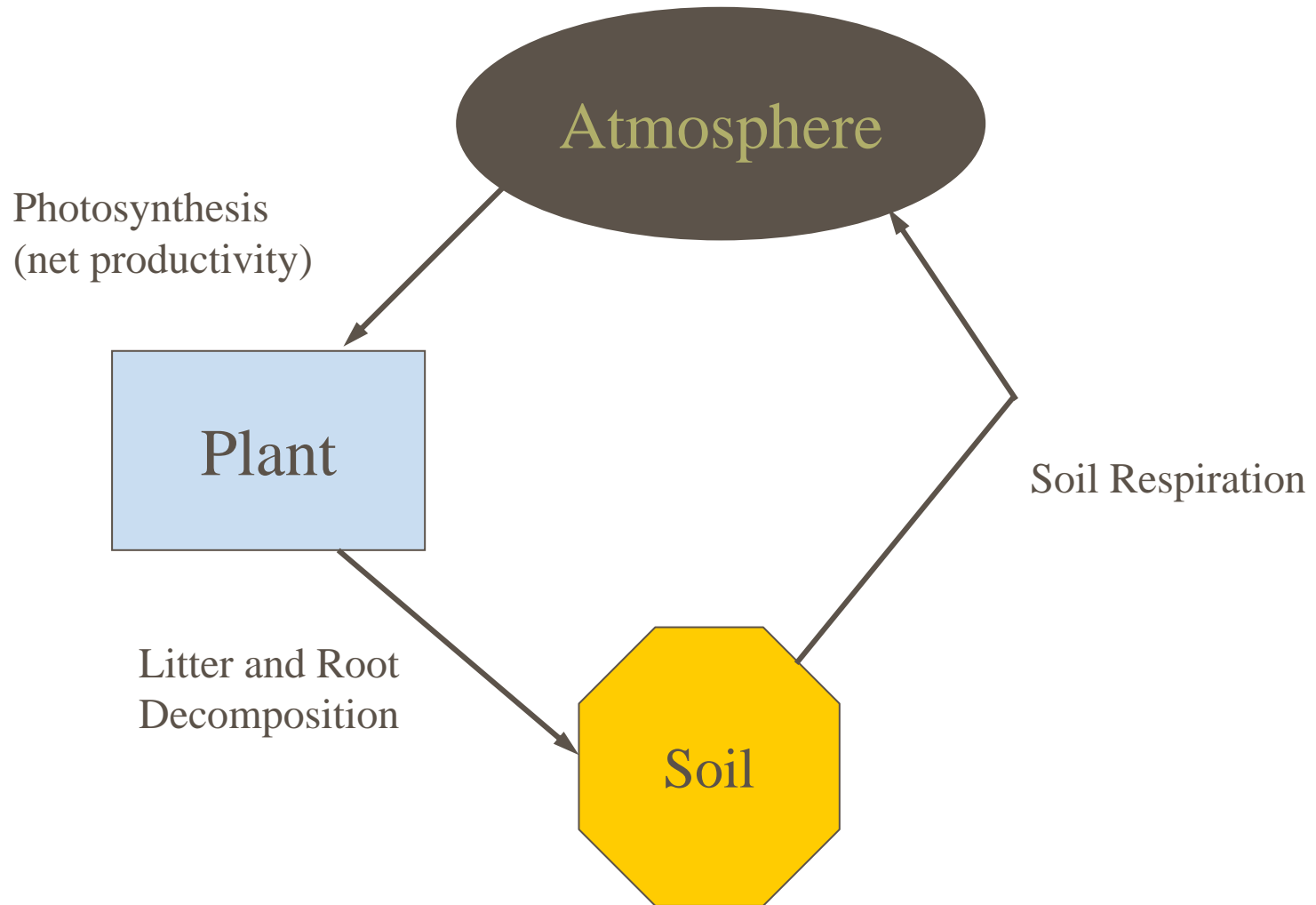
Ocean







Ecosystem Carbon Cycle





Surface Energy Balance

Atmosphere

Incoming Radiation

Fraction
Reflected
(albedo)

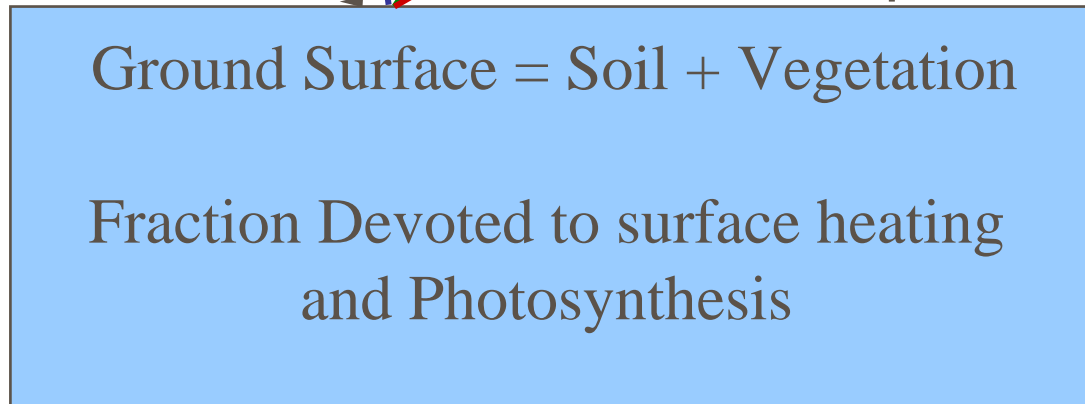
Lost as Latent
Heat Flux (evaporation
and evapotranspiration)

Lost as Sensible
Heat Flux

Lost as Long-wave
Radiant Heat

Ground Surface = Soil + Vegetation

Fraction Devoted to surface heating
and Photosynthesis



The Surface Energy Balance: Key Points

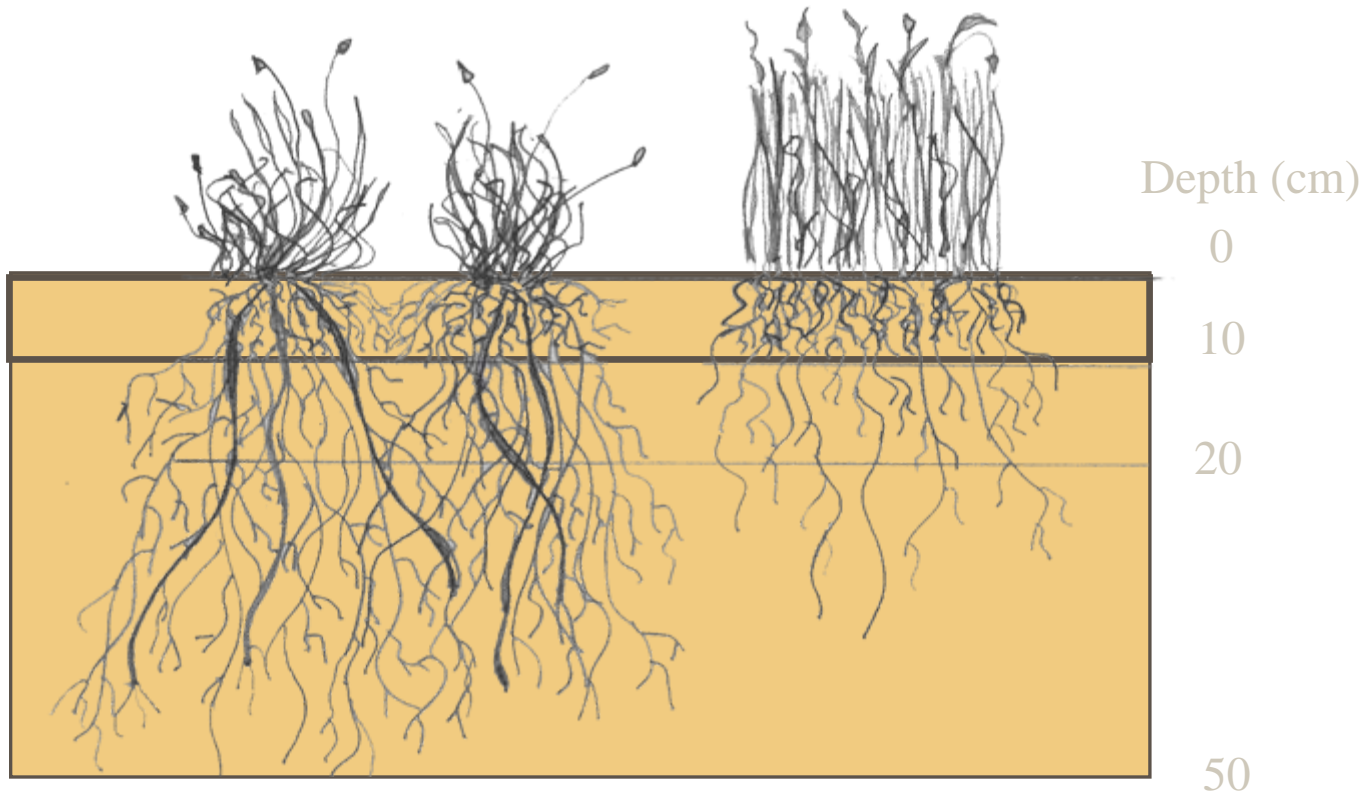
- *Sensible heat flux*: heat loss through conduction and convection. Can cause surface warming.
- *Latent heat flux*: heat loss occurs through evaporation and evapotranspiration. Energy is absorbed by water molecules and is transported away from the surface. Can cause surface cooling.
- *Albedo*: reflected radiation – radiation that is unavailable to heat the earth's surface

Mediterranean Climate

- Cool wet winters
- Hot dry summers
- Weathering summer drought
 - Perennial strategy
 - Annual strategy



Spring

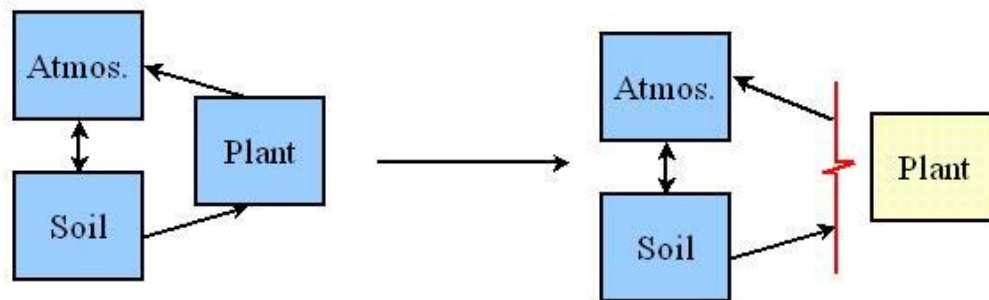
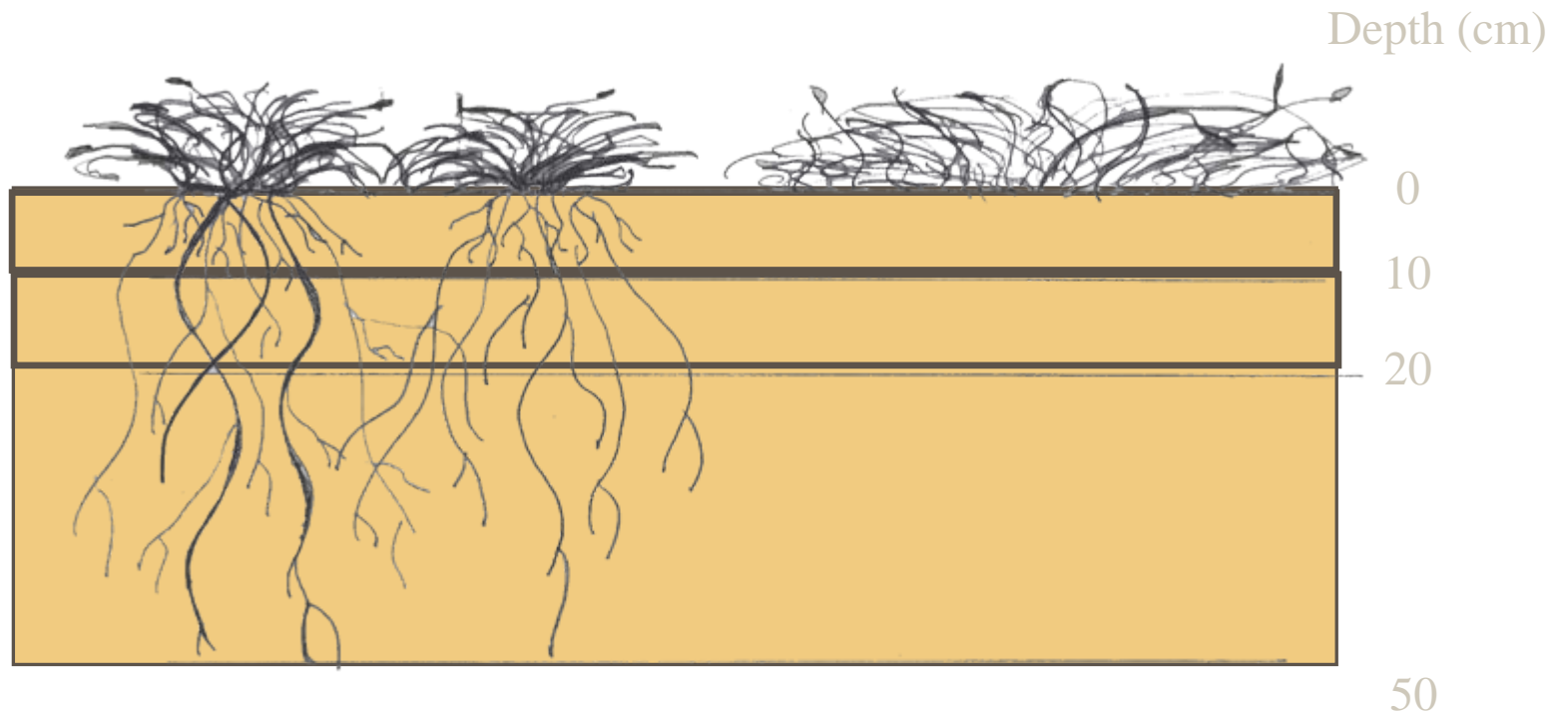








Summer







Measured Carbon Cycle Variables

Soil Inputs

- Aboveground plant growth
- Belowground Growth and Turnover (Roots)

Soil Outputs

- Soil respiration

Controlling Variables

- Soil temperature
- Soil moisture
- Plant Litter chemistry

Measured Variables: Energy and Water

Energy and Water Inputs

- Solar Radiation
- Precipitation

Controlling Variables

- Soil temperature
- Air Temperature
- Soil Moisture
- Relative Humidity

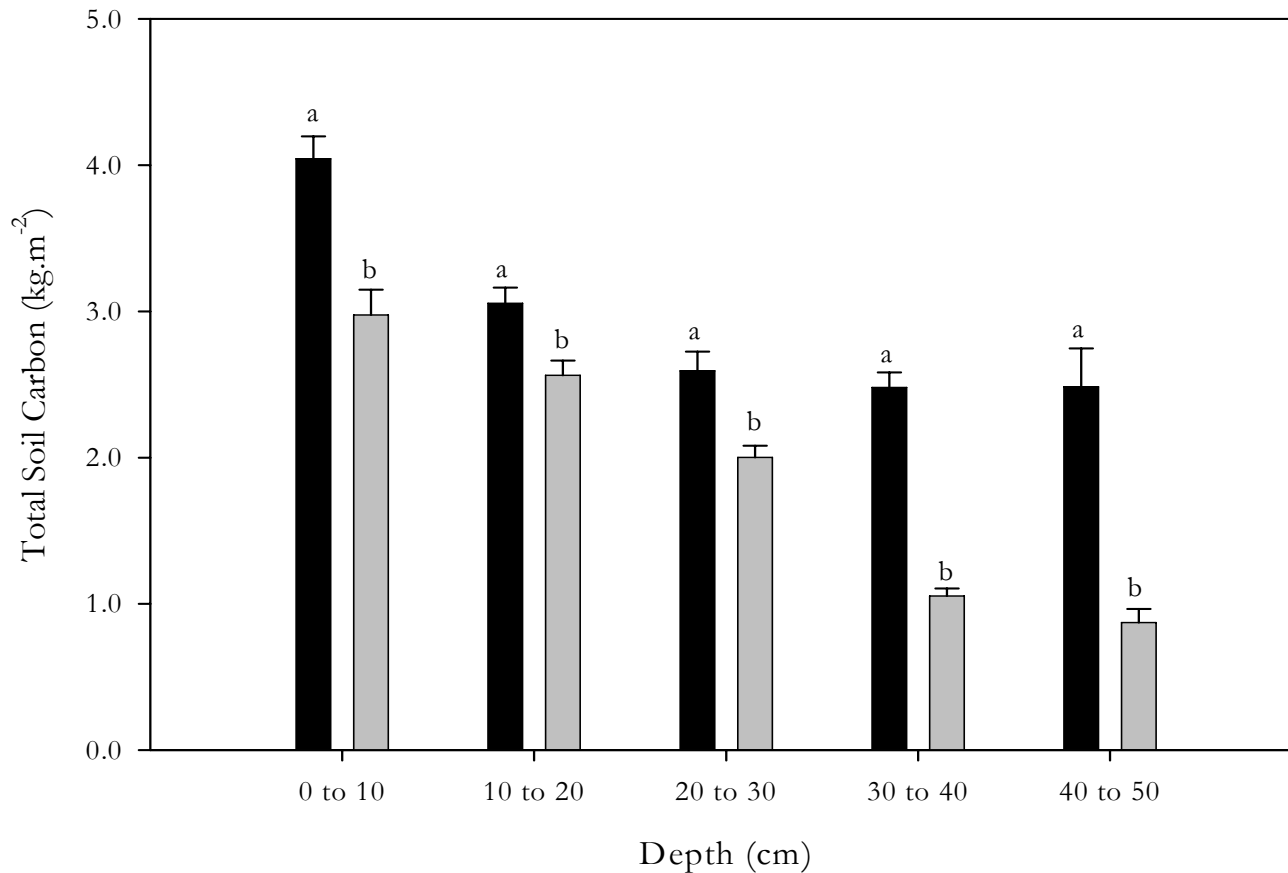
Water and Energy Outputs

- Evaporation (Latent Heat Flux)
- Sensible Heat Flux
- Soil Heat Flux

Some Results

Soil Carbon at the Bolinas Lagoon Preserve

Total Soil Carbon, Native Perennial and Exotic Annual Grass Communities, Bolinas Lagoon Preserve

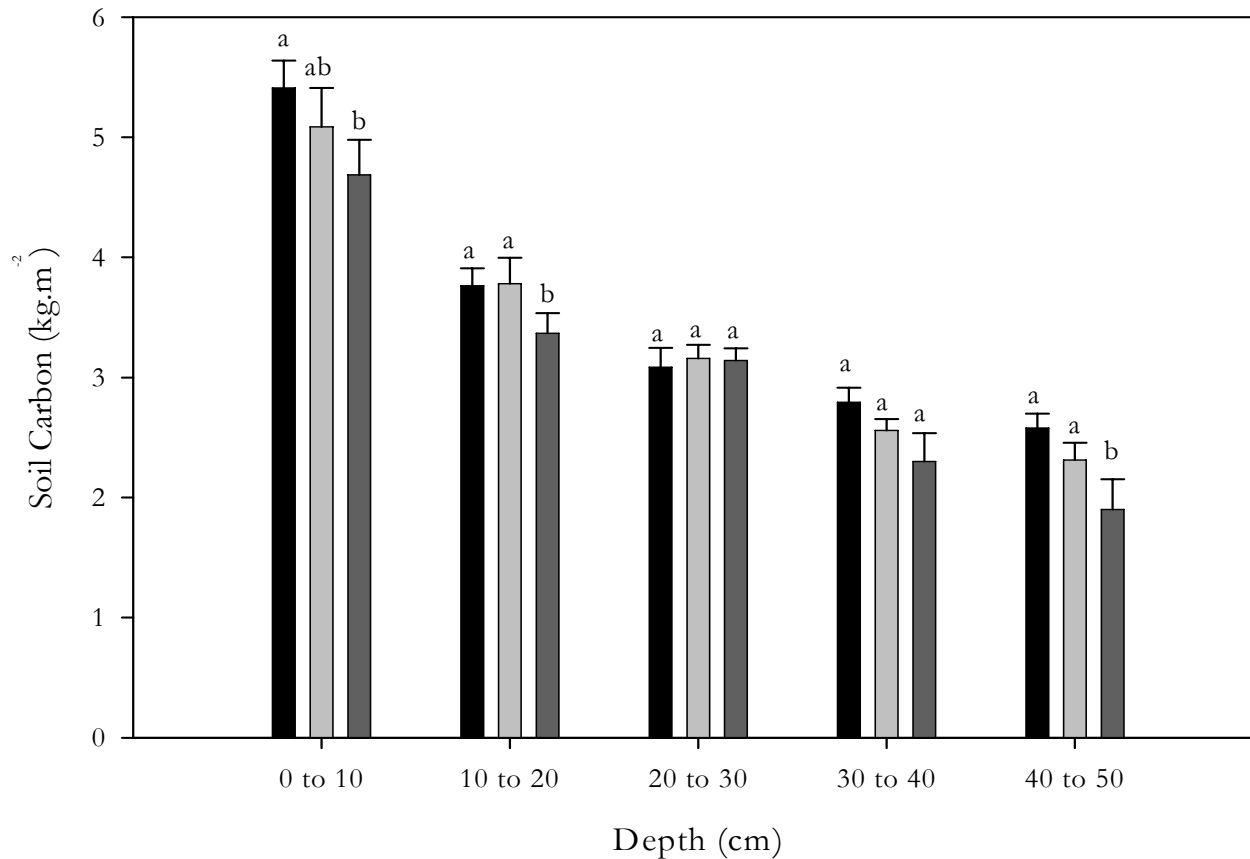


Native grasses (BLP)
Bromus carinatus
Elymus glaucus

■ Bromus carinatus and Elymus glaucus (native)
■ Mixed Exotic Annual Grasses

Soil Carbon at Tennessee Valley

Total Soil Carbon for Native Perennial and Exotic Annual Grass Communities, Tennessee Valley Field Site, GGNRA.



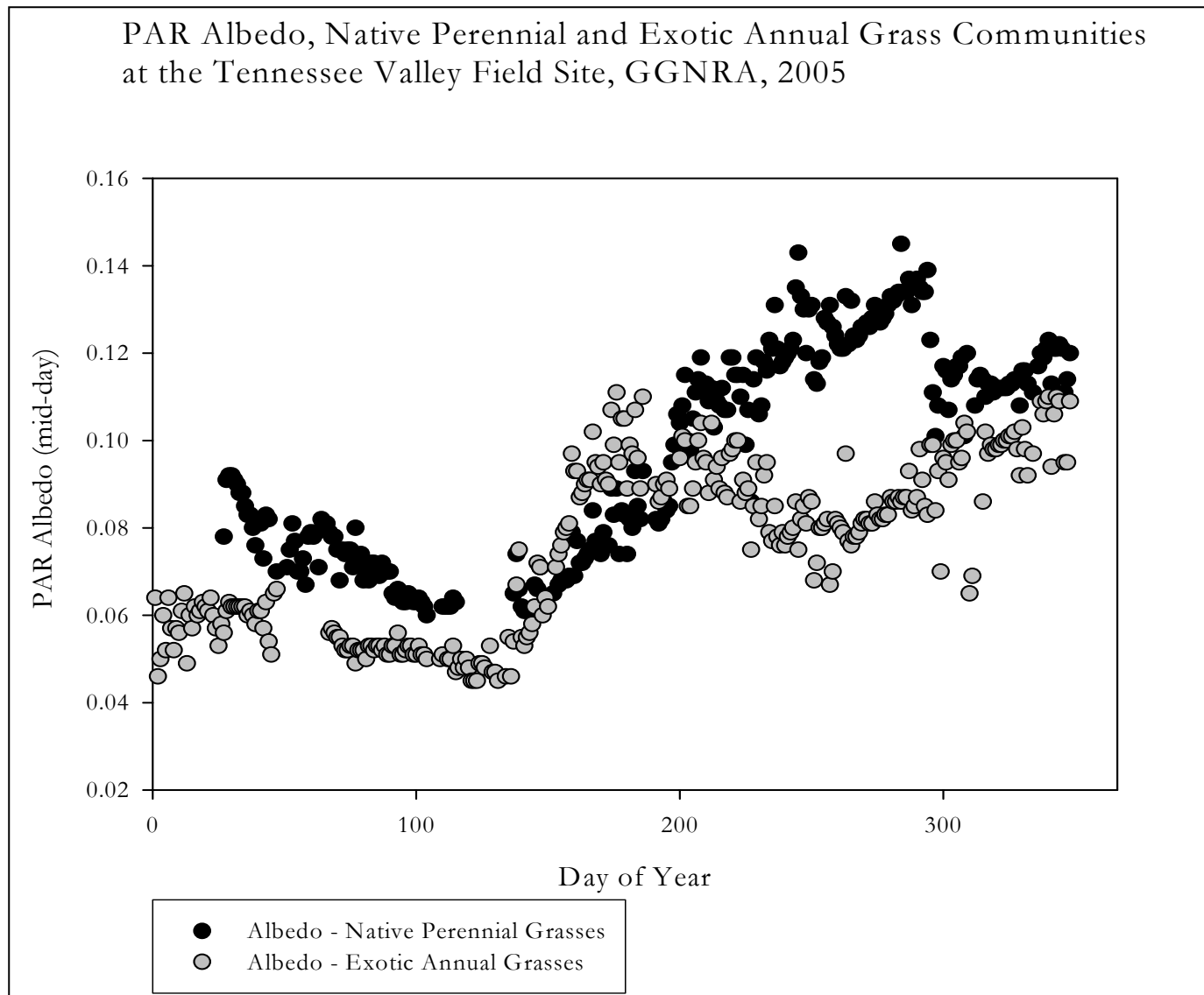
Native grasses (TV)

Festuca rubra

Agrostis halli

Soil Carbon Differences After Exotic Grass Invasion

- Soil Carbon Loss per $\text{m}^2 = 5 \text{ kg}$
- Soil Carbon Loss per acre = 20 metric tons
- Soil Carbon Loss in Marin County =
6 million metric tons (1,346 km^2 land area).
- Soil Carbon Loss in 10 million acres across California = 200 million metric tons



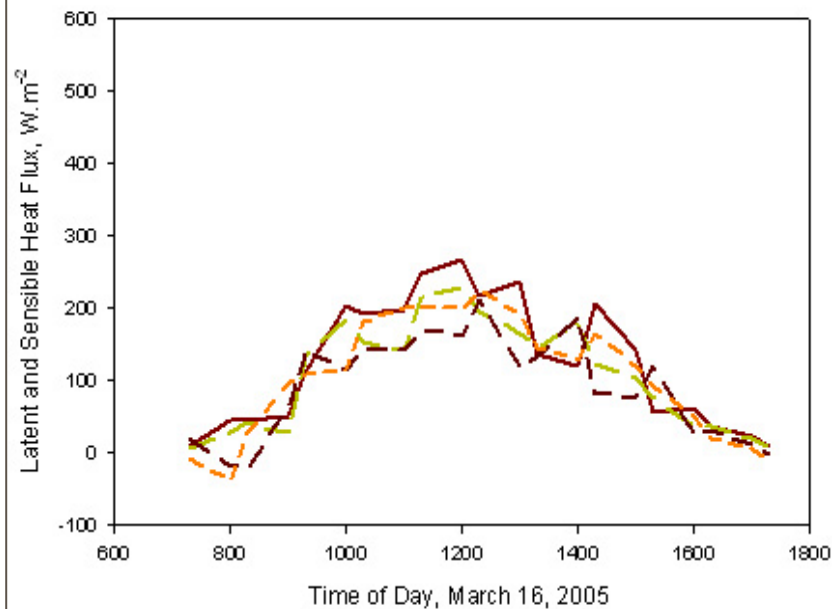
Mid-day albedo values for native perennial and exotic annual grass communities at the Tennessee Valley field site in 2005. Albedo values are higher for perennial grasses during most seasons of the year, leading to lower radiant energy capture.

Temperature Effects due to Differences in Albedo

- Average Mid-day Temperature Difference of 1.2 °C.
- Maximum Mid-day Summer Temperature Difference of 6 °C.

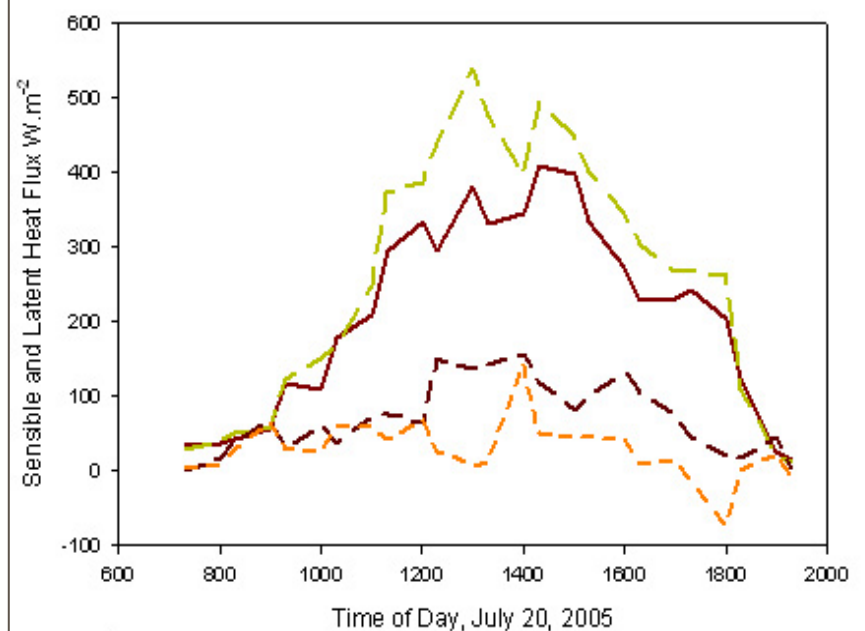
Daily Sensible and Latent Heat Flux Values

Sensible and Latent Heat Flux, Native and Exotic Grass Communities, Tennessee Valley GGNRA



— Sensible Heat Flux, Native Grasses
- - Sensible Heat Flux, Exotic Grasses
- - Latent Heat Flux, Native Grasses
- - Latent Heat Flux, Exotic Grasses

Sensible and Latent Heat Flux, Native and Exotic Grass Communities, Tennessee Valley GGNRA



— Sensible Heat Flux Native Grasses
- - Sensible Heat Flux Exotic Grasses
- - Latent Heat Flux, Native Grasses
- - Latent Heat Flux, Exotic Grasses

In Conclusion

- If we can generalize our findings to other regions in CA, the invasion of annual grasses from Mediterranean Europe has resulted in the transfer of millions of tons of carbon from terrestrial storage to the atmosphere, and thus contributed to global climate change.
- Annual grass invasion has resulted in elevated surface temperatures by greater than 6 °C (10.5 °F) during hot summer months due to changes in albedo.

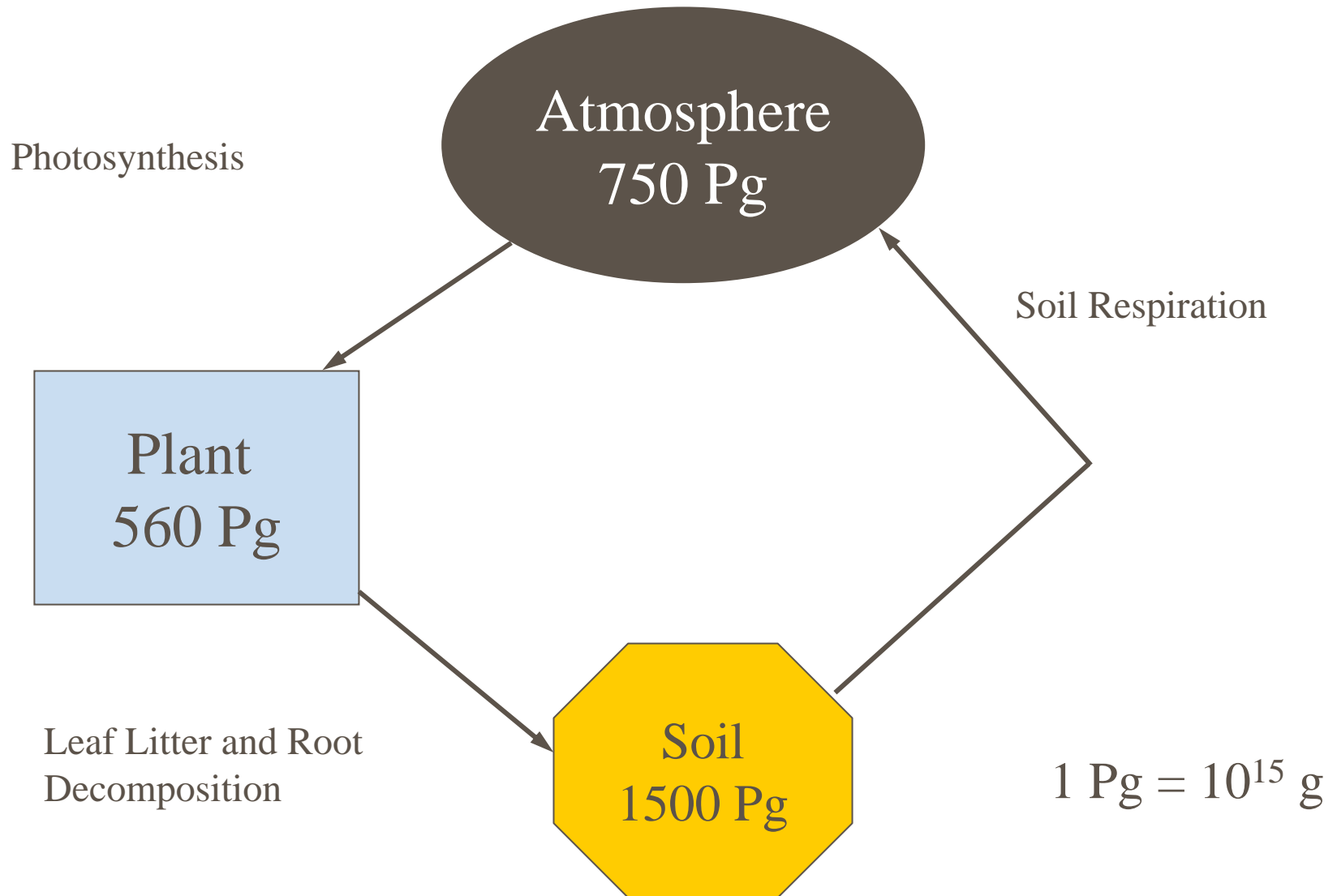
Policy Implications

- Restoration of coastal perennial grasslands may be both a strategy for carbon sequestration and a step towards reestablishing one of California's most diverse ecosystems.

Thank You!

John Harte, Dennis Baldocchi, Carla D'Antonio, Ted Hehn, my research assistants, The UC Berkeley Energy and Resources Group, The NASA Earth System Science Program, The National Park Service, The Bolinas Lagoon Preserve, The Kearney Foundation for Soil Science, The Berkeley Atmospheric Science Center.

Global Carbon Cycle: Major Terrestrial Carbon Reservoirs and Net Flows



Grass differences in morphology and phenology that could affect the carbon, water and energy cycles

- Native perennials are dense and bunchy. Exotic annuals are sparser and continuous. (radiation capture, soil evaporation, soil moisture).
- Native perennial grasses are long-lived. Exotic annuals live a single season and die after seed production. (litter quality, litter quantity, soil moisture, transpiration, soil respiration).
- Native grasses are deep-rooted. Exotic annuals have shallow roots. (soil moisture, soil temperature, transpiration, soil respiration, locations of soil carbon inputs).